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Spray Spectrum Modifications Through Changes in Airspeed to Minimize Drift

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Abstract. *Management of droplet size is one of the key components to minimizing spray drift, which can be accomplished in-flight by changing airspeed. Studies were conducted measuring spray droplet spectra parameters across airspeeds ranging from 100-140 mph (in 5 mph increments). In general the volume median diameters decreased 30-50% as airspeed increased with similar increases in the percent of the spray volume less than 100 µm. To determine the extent to which these changes in droplet spectra data impacted downwind drift, AgDISP was employed to estimate how varying airspeed along sequential flights swaths near a downwind field edge impacted total off field spray drift. Spray drift was modeled across multiple sequential spray swaths at both constant airspeeds across all swaths and at scenarios where near field edge swaths were flown at lower airspeeds (thus larger droplet sizes) to determine the level to which spray drift is reduced.*

Keywords. Aerial application, aerial spraying, spray deposition, spray drift

Introduction

Spray drift has always been one of the major concerns in the application industry. Spray drift is defined by the U.S. Environmental Protection Agency (EPA) as "…the physical movement of pesticide droplets or particles through the air at the time of pesticide application or soon thereafter from the target site to any non- or off-target site" (EPA, 2001). There is a large body of literature, spanning several decades, detailing the degree of spray drift resulting from agricultural applications as a result of meteorological conditions (Fritz, 2006; Thistle, 2000; Teske and Thistle, 1999; Yates et al., 1967), equipment type and operational parameters (Hoffmann and Tom, 2000; Nordby and Skuterud, 2006; Salyani, 1992), crop type (Franz et al., 1998; Lawson and Uk, 1979) and spray material (Kirk, 2000). All of these studies provide a solid foundation detailing principal causes of spray drift and the magnitude and characteristics of the drifting material.

Droplet size has long been recognized as one of the primary factors affecting off-target spray movement (Gil and Sinfort, 2005; Hewitt et. al., 2001; Hewitt, 2000). The process and operating conditions influencing spray spectrum are well defined and measurable (Kirk, 2007). Generally, larger droplet sprays result in less drift than smaller droplet sprays. Spray droplet spectrum can be influenced and modified by changes in nozzle type and setup (Kirk, 2007; Bouse, 1994), spray solution (Hewitt et al., 1993), and airspeed (Kirk, 2007).

The Spray Drift Task Force (SDTF) compiled a database of reported spray drift data (Hewitt et al. 2001) which supported the further development and evaluation of the spray drift model AgDRIFT (Bird et al, 2002; Hewitt et al., 2001). The computational algorithms of the aerial spray model AgDISP make up the aerial spray drift model component of the AgDRIFT model (Bird et al., 2002). The AgDISP allow users to estimate how changes in operational parameters potentially influence the movement and fate of aerially applied sprays.

Objectives

The objectives of the study were to characterize droplet size resulting from a decreased airspeed relative to a typical application speed and to model downwind movement to determine potential drift reduction.

Materials and Methods

The work was completed in two separate phases, droplet sizing and AGDISP modeling. The methods and procedures used for each are discussed below.

Application Setups

For this study two operational airspeeds were considered; 140 and 120 mph. The nozzle selected for used was the CP-11TT 4008 (CP Products, Tempe, AZ). The boom configurations used in the AGDISP modeling were setup to result in a 2 gpa application rate. The flowrate for the 11TT 4008 operating at 35 psi was 0.75 gpm and with a 65% effective boom, for a 2 gpa rate at an airspeed of 140 mph, 49 nozzles were required. Slowing down to 120 mph, at the same pressure, with the same number of nozzles, the application rate increased to 2.35 gpa. For this work, it was assumed that the aircraft had a flow controller that corrected the application rate by modifying spray pressure. Reducing the pressure to 25 psi, the nozzle flowrate reduced to 0.64 gpa, reducing the application rate to 2 gpa. Therefore the two application setups were 140 mph at 35 psi and 120 mph at 25 psi. Droplet size measurements were made at these conditions.

Droplet Size Measurements

Droplet sizing was conducted in the USDA-ARS high speed wind tunnel. Droplet sizing was conducted using the Sympatec Helos laser diffraction droplet sizing system (Sympatec Inc., Clausthal, Germany). The Helos system uses a 623 nm He-Ne laser and was fitted with an R5 lens, which resulted in a dynamic size range of 0.5 µm to 875 µm in 32 sizing bins. Tests were performed within the guidelines provided by ASTM Standard E1260: Standard Test Method for Determining Liquid Drop Size Characteristics in a Spray Using Optical Nonimaging Light-Scattering Instruments (ASTM, 2003). Droplet sizing data measured included volume median diameter ($D_{v0.5}$), the 10% and 90% diameters ($D_{v0.1}$ and $D_{v0.9}$), and the percent volume less the 100 µm as defined by ASTM Standard E 1620 (ASTM 2004). Also determine and reported were Relative Span (($D_{V0.9} – D_{V0.1}$) / $D_{V0.5}$)) and the percent volume of spray in droplets size less than or equal to 100 µm (%<100 µm).

The nozzle was fitted onto a plumbed spray boom section in the high speed air section of the wind tunnel. For each operating condition tested, the full spray plume from the nozzle was traversed through the Sympatec's laser. Three replications were made at each operating condition.

AGDISP Modeling

A series of modeling runs were conducted incorporating both operational treatments into a 20-pass application near the edge of a field. Initially, all 20 passes were made at the 140 mph airspeed. Additional application scenarios examined the effects of making near field edge passes at the 120 mph airspeed, with the thought that the slower airspeed, which produces a larger droplet spray, would reduce off-target movement. Each additional application scenario added an additional 120 mph pass near the edge of the field, until all 20 passes were made at 120 mph. For example, the first scenario had all 20 passes at 140 mph; the second had one pass at the field edge made at 120 mph, and the other 19 at 140 mph; the third had two passes near the edge of the field made at 120 mph, and the other 18 at 140 mph; and so on.

For the AGDISP model, the selected aircraft was an AT-402 with a 65 ft swath and a 3 m release height. No canopy was used but the surface roughness was 0.3 in. Wind speed was set to 5 mph and perpendicular to the spray swaths. Temperature was set at 70° F with a relative humidity of 60% and moderate daytime stability. Evaporation effects were not considered. Modeling results included deposition from 0 to 100 m downwind of the first spray swath (i.e. edge of the field) and the vertical spray at 100 ft downwind.

Results and Discussions

Droplet Size Measurements

Droplet size measurements demonstrated a 20% increase in $D_{V0.5}$ with the decreased airspeed and spray pressure (Table 1). Likewise, the percent of the spray volume at 100 µm or less decreased 20% (Table 1). These values were input into the AGDISP model for the modeling runs.

Table 1. Droplet size characteristics measured for CP-11TT 4008 nozzle operating in a high speed wind tunnel spraying Powermax at the indicated airspeeds and spray pressures.

Airspeed (mph)	Spray Pressure (psi)	$D_{V0.5}$ (μm)	$D_{V0.1}$ (μm)	$D_{V0.9}$ (μm)	Relative Span	%<100 μm
140	35	223	85	399	1.41	13.3
120	25	269	97	495	1.48	10.6

AGDISP Modeling Results

Downwind Deposition

Deposition at 0, 50, and 100 m downwind was compared over all application scenarios. At 0 m downwind, optimum reduction in deposition (12%) occurred with one, 120 mph pass included (Fig. 1). Adding additional 120-mph passes did result in minor decreases of downwind deposition up to an additional five, 120-mph passes, but beyond that, further additional 120-mph passes provided no change in deposition. At 50 m downwind, optimum reduction in deposition (10%) occurred with three, 120-mph passes included (Fig. 1). While additional passes did further decrease deposition, these changes were minimal (10% at three, 120-mph passes to 14%+ at 20, 120-mph passes). At 100 m downwind, there was no obvious optimum level of reduction, but the greatest step decrease occurred with two, 120-mph passes (<4% at one, 120-mph passes and >8% at two, 120-mph passes). While additional reductions occurred with increasingly more 120-mph passes, stepwise decreases were minimal after the addition of three, 120-mph passes.

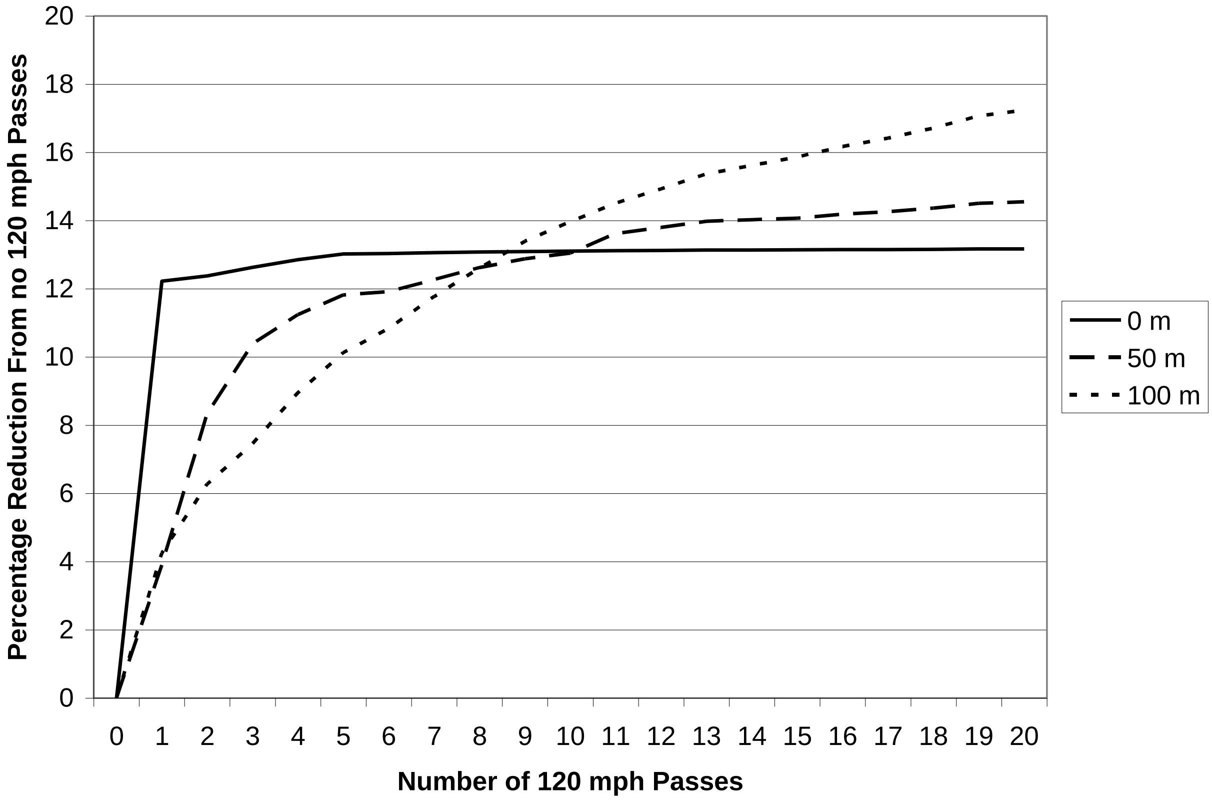

Figure 1. Percentage reduction in deposition at 0, 50 and 100 m downwind by number of spray passes made at 120 mph as compared to all 20 spray passes made at 140 mph (i.e. no 120-mph passes).

Vertical Flux

The vertical flux profile resulting from AGDISP (flux in mg/cm^2 at each 0.5 m height interval) was used to calculate a total flux over the entire profile assuming a 1 m wide column. Flux is a measure of the amount of spray material moving through a specific area as a result of the spray treatment. The vertical flux profile is this measure over the vertical profile from the ground to a height of 130 ft. This total flux was then compared over all application scenarios. There was no obvious optimum reduction, but the greatest step decreases occurred at with one and two, 120-mph passes included (Fig. 2)

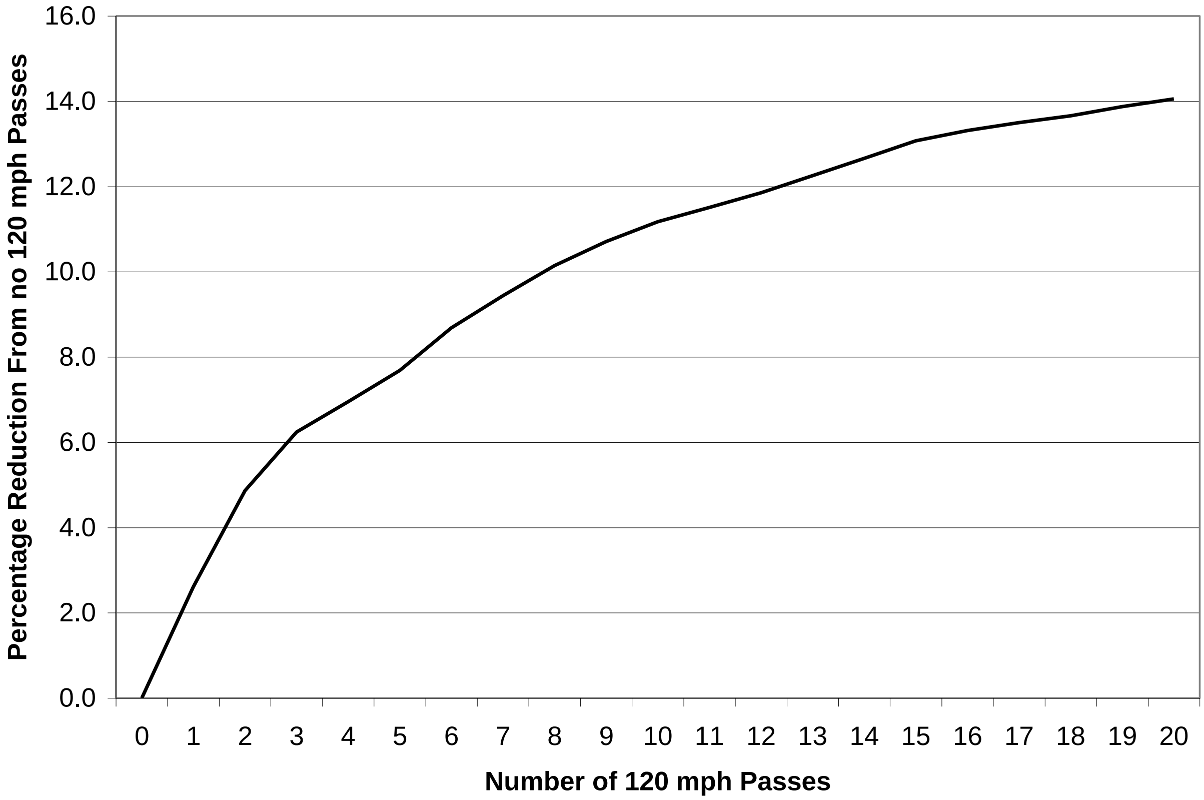

Figure 2. Percentage reduction in total vertical flux by number of spray passes made at 120-mph as compared to all 20 spray passes made at 140 mph (i.e. no 120-mph passes).

Discussion and Conclusions

Management of droplet size is one of the key components to minimizing spray drift, which can be accomplished through a number of options including changing airspeed. This study explored the potential for drift minimization through modifications of the spray spectrum by reductions in application airspeed. Reducing airspeed increased overall droplet sizes and reduced the number of finer droplets. AGDISP modeling demonstrated that the addition of slower speed passes near the edge of a field can potentially reduce the off-target movement and deposition of applied material. The reduced speed passes do not add a significant increase to the overall time required for application. For a one-mile long spray swath, the 120 mph passes require only an additional five seconds over the 140 mph passes. Based on the results presented, two or three lower speed passes near the edge of the spray field are enough to result in 6 to over 10% reductions in off-target movement.

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